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GROUNDWATER QUALITY IN SASKATCHEWAN: HYDROGEOLOGY, QUALITY CONCERNS, MANAGEMENT

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ABSTRACT

In Saskatchewan, 90 percent of the rural population and 80 percent of municipalities depend on groundwater supplies. Management, supply and protection of this resource is divided among many groups with different objectives. A comprehensive review of groundwater concerns and a synthesis of organizations dealing with these concerns was needed. The origin of groundwater in the province, specific concerns regarding water supply, use and contamination and the legislative and management programs delivered by provincial and federal agencies in Saskatchewan are discussed in detail.

Provincial legislation relating to water resource management aimed at water supply and conservation and legislation relating to water quality aimed at public health, the oil and gas industry and environmental protection is summarized. Five principal agencies administer this legislation as well as provide monitoring, mapping, policy development and water analyses services. Details of these services and technical and financial assistance available in the province are discussed. A listing of agency contacts is provided.

RÉSUMÉ

En Saskatchewan, 90 p. 100 de la population rurale et 80 p. 100 des municipalités dépendent d'approvisionnements en eaux souterraines. La gestion, l'exploitation et la protection de cette ressource relèvent de nombreux groupes possédant des objectifs différents. Une analyse globale des préoccupations relatives aux eaux souterraines et une synthèse des organisations chargés de répondre à ces préoccupations s'imposaient. Le présent rapport porte sur de nombreux sujets: origine des eaux souterraines de la province, préoccupations précises relatives aux approvisionnements, utilisation et contamination de ces eaux, ainsi que programmes de législation et de gestion menés en Saskatchewan par les organismes provinciaux et fédéraux.

On donne par ailleurs un résumé de la législation provinciale portant sur la gestion des ressources en eau qui visent à protéger les approvisionnements ainsi que de la législation portant sur l'industrie pétrolière et gazière, sur la protection de l'environnement et sur la qualité de l'eau qui visent à protéger la santé publique. Cinq grands organismes administrent cette législation tout en étant chargés d'exploiter des services de contrôle, de cartographie, d'élaboration de politiques et d'analyses de l'eau. Il est question dans le détail de ces services et de l'aide technique et financière existant dans la province. Enfin, une liste de contacts est donnée.

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INTRODUCTION

This report describes the existing groundwater resources and quality in Saskatchewan, environmental concerns relating to groundwater quality, and the tools

available for groundwater management and protection (legislation, institutions, and programs). It is one of a series that covers the ten provinces and two territories of Canada.

The primary focus of this report is on groundwater quality, but groundwater resources and management of these resources are also discussed in recognition of the close relationship between quality and quantity. Also discussed are instruments for management that are directed primarily at protecting surface water or drinking water, but can or are being used to protect groundwater as well. It should also be recognized that in some cases groundwater is protected mainly because it may be a pathway for contamination of surface water.

The report is organized into five sections:

1) the hydrogeology and related information;

2) groundwater quality concerns, caused either by human activity or of natural origin;

3) the legal basis for groundwater management ("legislative instruments");

4) the provincial institutions for groundwater management ("institutional instruments"); and

5) specific programs (i.e. monitoring, data collection, classification and management plans, technical and financial assistance, etc.).

The report was produced jointly by Environment Canada (the State of the Environment Reporting Branch and the National Hydrology Research Institute) and the Saskatchewan Research Council. Many provincial and federal officials provided support and assistance in the form of information and reviews. Because the responsibility for our water resources lies primarily with the provincial governments, and it is the provincial officials who deal with groundwater matters on a regular basis, their support and collaboration is particularly valuable.

This report, together with those of the other provinces and territories, has several purposes. First, the reports will form the basis for a forthcoming overview of groundwater in Canada. That overview will be part of a new federal effort to report on the state of the environment of Canada, an effort tied to the goal of sustainable development. Second, the reports attempt to provide comprehensive information on the different concerns and activities related to groundwater in each province and territory. Thus, they can be useful for anyone involved with groundwater, be they the public, consultants, industry or officials of different levels of government. In effect, the reports can form a bridge between different groups and help them to better understand each others' concerns, goals and endeavours. Finally, the reports provide a description of how groundwater c ncerns are dealt with in the various jurisdictions of Canada. This may lead

to increased awareness and form the basis for future collaboration between different jurisdictions.

As will be apparent throughout the report, the tools for groundwater management turn out, as often as not, to be legislation, institutions and programs for overall water management, or for the management of waste, pesticides and other potential pollutants, rather than for groundwater management alone. This may reflect the nature of groundwater management, indicating that groundwater and its management should be considered as part of a much larger picture and not as an isolated concern.

The description of the hydrogeology of Saskatchewan presented in this report is based largely on a forthcoming publication of the Saskatchewan Research Council, "Hydrogeology of Southern Saskatchewan" by Harm Maathuis, supplemented by information from Garth van der Kamp and Uwe Roeper. Aside from this much more thorough document, this is the only summary overview of Saskatchewan hydrogeology.

1. HYDROGEOLOGY

1.1 PHYSIOGRAPHY, CLIMATE, RECHARGE AND DRAINAGE

The southern two thirds of Saskatchewan lie within the Western Glaciated Plain groundwater region, equivalent to the large sedimentary basin of western Canada south of the permafrost zone (Lennox et al., 1988). The northern part, beginning with the Churchill River area, is part of the Precambrian Canadian Shield and extends into the zone of discontinuous permafrost.

Topographically, most of the province is flat to rolling country, with local hummocky relief of 30 to 60 m. Relief between major uplands and adjacent lowlands may be up to several hundred metres. Lake plains on the other hand, such as those around Regina, are almost without relief (Rump and Harper, 1980). Surface topography exerts a controlling influence on groundwater flow, both at shallow depths and on a basin-wide scale. Major rivers act as local drains (Lennox et al., 1988).

Saskatchewan's climate ranges from semi-arid in the south to subhumid continental in the north (Richards and Fung, 1969). The mean annual precipitation ranges between 279 mm in the southwest and 457 mm in the northeast (Rump and Harper, 1980). Groundwater recharge occurs mainly during snow melt in the Spring and during the months of May and June (early summer rains). Annual recharge may range from some tens of mm in surficial aquifers to several mm in shallow intertill and bedrock aquifers, and to tenths of mm in deep aquifers. Shallow recharge is often restricted to surface depressions where ponds are created during snow melt and runoff (Maathuis, 1990). Areas higher than the surrounding plains (such as the Cypress Hills 700 m above the Alberta Plain) are also regional recharge areas; in addition, the Cypress Hills also affect deep basin flow (Lennox et al., 1988).

Most of Saskatchewan's surface waters drain into Hudson Bay. Only a small portion along the international border drains into the Gulf of Mexico.

1.2 HYDROGEOLOGY OF THE INTERIOR PLAINS

The Interior Plains are underlain by nearly horizontal sedimentary strata which range in age from Cambrian to Quaternary. The thickness of these sedimentary strata ranges from 0 m at the southern edge of the Shield to 3,200 m in the southeast.

The sedimentary strata form, in descending order, four distinct hydrostratigraphic units (Lennox et al., 1988; Maathuis, 1990):

- an upper clastic unit,

- a middle unit of carbonates and evaporites,

- a lower clastic unit, and

- the underlying Precambrian crystalline basement rock.

The hydrogeological setting of southern Saskatchewan can be simplified and, in ascending order, consists of an impermeable base, a basal aquifer system and an upper aquitard (Maathuis, 1990). The impermeable base is formed by the top of the Precambrian basement rock. The basal aquifer system is a complex unit composed of the lower clastic unit, the carbonates and evaporites, and the lower portion of the upper clastic unit. The remainder of the upper clastic unit forms a thick aquitard which confines the basal aquifer system. Within this aquitard, Cretaceous, Tertiary and Quaternary sands occur which form important sources of potable water supply.

In the terminology of Saskatchewan hydrogeology, bedrock implies material which is preglacial in age. Bedrock aquifers and Quaternary aquifers are discussed in separate sections.

1.2.1 Bedrock Aquifers and Aquitards

The deeper permeable formations of the basal aquifer system contain mostly brackish or saline water which is sometimes used for enhanced oil recovery. Permeable subunits of this system, the lower clastic unit (Deadwood and Winnipeg Formations) in particular, are also used for disposal of liquid wastes.

Throughout southern Saskatchewan, except in a fringe along the southern edge of the Shield, Cretaceous aquitards are important in that they separate the fresh-water yielding bedrock aquifers and Quaternary aquifers from the saline-water yielding aquifers of the basal aquifer system. The combined thickness of the Cretaceous aquitards is about 1,200 m at the international border and decreases northward to zero metres. The Cretaceous aquitards are composed of weakly consolidated silts and clays. The permeability of the aquitards is likely in the 10^{-10} to 10^{-12} m/s range (Maathuis, 1990). Supplies of potable groundwater are thought to exist in the Ordovician, Silurian and Devonian limestones and dolomites which outcrop near the edge of the Precambrian Shield close to the Manitoba border (Figure 1). The limestones and dolomites in this area form a complex aquifer system which might be interconnected with surface water bodies in the area. The aquifer is referred to as the Cumberland aquifer (Meneley, 1972; Maathuis, 1990). Settlement in this area is sparse though, and to date no water supply wells have been completed in this aquifer (Roeper, personal communication, 1988).

The Lower Cretaceous Mannville Group geologically is part of the upper clastic unit, but hydrogeologically it is part of the basal aquifer system. It forms an aquifer

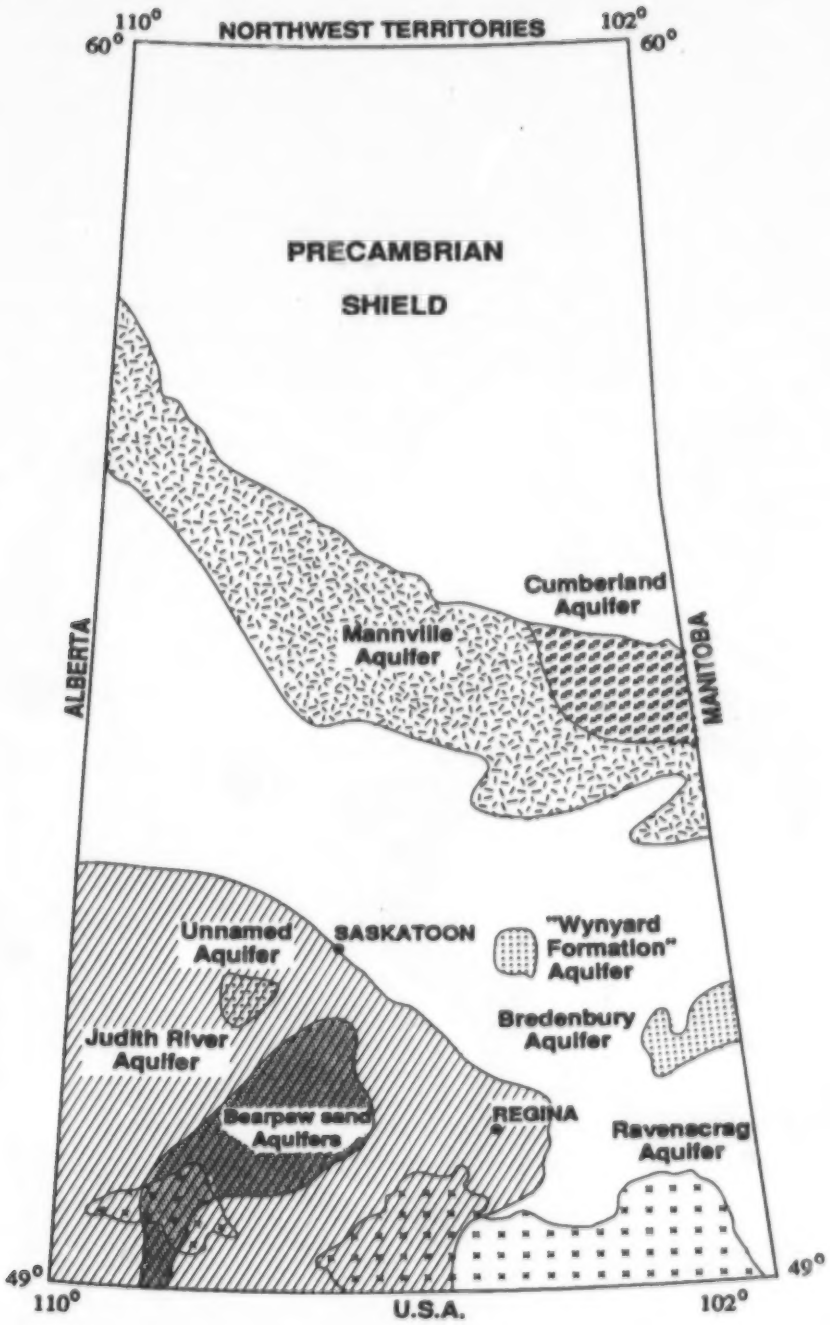

Figure 1. Freshwater bedrock aquifers in Saskatchewan (After Maathuis, 1990)

(Mannville aquifer) which occurs throughout southern Saskatchewan but it provides potable water only in a fringe along the southern edge of the Precambrian Shield (Figure 1). In this area it is overlain by up to 300 m of glacial deposits, mainly till.

The Upper Cretaceous Judith River Formation forms a major aquifer in west-central and southwestern Saskatchewan (Figure 1). The aquifer is underlain and overlain by Cretaceous silts and clays, and it is locally overlain by glacial deposits. The Judith River aquifer (Kewen and Schneider, 1979; Whitaker, 1982) is a major source of water supply for municipal, industrial, and domestic users. In the Kindersley area and in southwestern Saskatchewan, water from this aquifer is also used for enhanced oil recovery from deeper formations.

The Eastend to Ravenscrag Formations are composed of sands and silts and include sandstone and coal layers. These formations form a single but complex aquifer unit in southern Saskatchewan along the international border. The aquifer is referred to as the Ravenscrag aquifer (Figure 1). In southeastern Saskatchewan the aquifer outcrops at the ground surface; in the southeast it is overlain by up to 100 m of glacial deposits, mainly till.

The various sand members of the Upper Cretaceous Bearpaw Formation form aquifers which are locally important as a source of water supply (Whitaker, 1982; Maathuis, 1990). The aquifers are under- and overlain by silt and clay members of the Bearpaw Formation. On a regional scale, little is known about the aquifers formed by the Bearpaw sand members. Therefore, only the general area in which these aquifers occur is shown in Figure 1.

Throughout southern Saskatchewan, isolated deposits of sands and gravels occur which are considered to be preglacial in age, but which have not been formally described and named. These deposits form local aquifers (Figure 1) which are used for domestic and municipal water supplies (Maathuis, 1990).

Minor bedrock aquifers include aquifers formed by:

i) fractured shale of the Odanah member of the Pierre Shale in the Rocanville-Esterhazy area (Schreiner and Maathuis, 1982);

ii) sands and gravels of the Cypress Hills and Wood Mountain Formations in the extreme southwestern part of Saskatchewan, which provide domestic and small municipal groundwater supplies.

Little is known about these aquifers and therefore, their extent is not shown in Figure 1.

1.2.2 Quaternary Aquifers and Aquitards

During the Pleistocene, Saskatchewan was covered several times by continental glaciers, except for the Cypress Hills and Wood Mountain Uplands in the extreme southwestern part of Saskatchewan. Quaternary deposits are up to 300 m thick but form only a relatively thin veneer of sediments compared to the total thickness of the sedimentary strata. However, aquifers within these deposits form important sources of water supply for municipal, industrial and domestic uses.

The Quaternary stratigraphy, in ascending order, may include the Empress Group, the Sutherland Group and the Saskatoon Group (Figure 2). Sands and gravels of the Empress Group (Whitaker and Christiansen, 1972) occur between bedrock and till, and form the buried valley and blanket aquifers. The Sutherland and Saskatoon Groups have been described by Christiansen (1968a,b). The Sutherland Group consists mainly of tills with minor occurrences of sands and gravels. The Saskatoon Group is subdivided into the Floral Formation, the Battleford Formation and surficial stratified drift. The Floral and Battleford Formations consist mainly of till with minor occurrences of sands and gravels. The sands and gravels between the till units of the Sutherland and Saskatoon Groups form intertill aquifers. Sands of the surficial stratified drift form surficial aquifers (Figure 2).

Aquitards are formed by tills, and locally by intertill and surficial silts and clays (Figure 2). The permeability of these aquitards is one of the most important hydraulic parameters. It determines rates at which aquifers are recharged, rates of contaminant migration and it affects groundwater flow patterns and water quality (Maathuis, 1990). The permeability of these aquitards may range from less than 10^{-11} m/s for the tightest unfractured materials to 10^{-7} m/s for heavily fractured materials near the groundwater surface. A review of permeability data for Saskatchewan is provided by Lennox et al. (1988) and Maathuis (1990). Tills and clays exposed at the ground surface tend to be oxidized and fractured to depths of 10 m or more (Cherry, 1987). Recent studies suggest that unoxidized till, in particular unoxidized Floral till, may have fracture permeability to a depth of 30 m or more (e.g. Keller et al., 1986, 1988; Fortin et al., 1991).

1.2.2.1 Buried Valley Aquifers

Preglacial valleys, cut into bedrock sediments, filled with sediments of the Empress Group and covered by tills, form major buried valley aquifers (Figure 3). The largest of these buried valley aquifers is the Hatfield Valley aquifer which extends for 550 km from the Cold Lake area near the Alberta border, across Saskatchewan to the Manitoba border. The aquifer, up to 30 km wide, is commonly between 30 and 50 m thick and is covered by up to 90 m of glacial deposits, mainly till (Maathuis, 1990). Other major buried valley aquifers are the Estevan Valley, Tyner Valley, Battleford Valley and Swift Current Valley aquifers (Figure 3). The thick tills which confine these

Saskatoon Group	Surficial stratified drift	Sand, gravel silt and clay	Surficial and alluvial aquifers, aquitards
	Battleford Formation	Till	Aquitard
	Floral Formation	Till	Aquitard
		Sand gravel, silt and clay	Intertill
		Till	Aquitard
		Sand, gravel, silt and clay	
Sutherland Group		Till	Aquitard
		Sand, gravel, silt and clay	Intertill aquifer
		Till	Aquitard
Empress Group		Sand, gravel, silt and clay	Buried valley and blanket aquifer
Cretaceous or Tertiary Bedrock			

Figure 2. Schematic illustration of Quaternary stratigraphy. lithology and associated hydrogeological units.

major buried valley aquifers generally appear to have very low permeability, limiting recharge to at most a few mm per year (van der Kamp, 1986; Keller et al., 1989).

1.2.2.2 Blanket Aquifers

Blanket aquifers are laterally extensive, continuous aquifers composed of unconsolidated sediments of the Empress Group. They typically occur along the flanks of the Hatfield Valley Aquifer and are hydraulically connected to this aquifer. Major blanket aquifers in Saskatchewan are the Pathlow, Meacham, and Wynyard-Melville aquifers (Figure 3). These aquifers are commonly between 20 and 30 m thick and are overlain by 50 to 100 m of drift, mainly till.

1.2.2.3 Intertill Aquifers

Throughout southern Saskatchewan, intertill aquifers have been developed for domestic and municipal supplies. Intertill aquifers are formed by sands and gravels

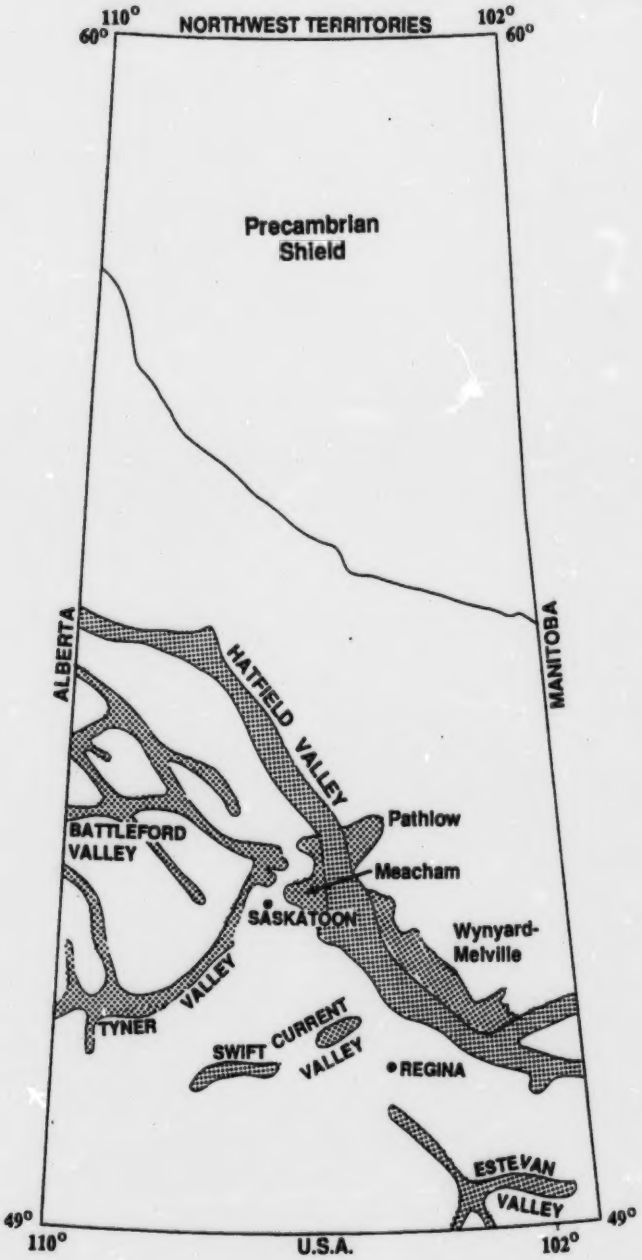

Figure 3. Buried - valley and blanket aquifers at interface between bedrock and Quaternary formations (After Maathuis, 1990)

between till units. They are found at various depths and vary widely in extent, both vertically and laterally, and in composition. The city of Regina uses water from these aquifers for its municipal water supply (Maathuis and van der Kamp, 1988). The Dalmeny aquifer, a shallow intertill aquifer north of Saskatoon, has been recently described by Fortin et al. (1991). Numerous intertill aquifers are known to exist but most of them have not been fully delineated, named, or described (Maathuis, 1990).

1.2.2.4 Surficial Aquifers

Surficial aquifers are found throughout southern Saskatchewan (Figure 4). They are composed of sands and gravels deposited in glacial lakes, rivers, and deltas during the final deglaciation of Saskatchewan. Although their extent is relatively well known from surficial geology and soils maps, surficial aquifers have not been studied extensively.

Extensive surficial aquifers occur along the North and South Saskatchewan Rivers in the area between Outlook and Nipawin. Another extensive surficial aquifer occurs in the Great Sand Hills area of southwestern Saskatchewan (Lane and Sykes, 1982). Alluvial deposits containing sandy materials are found in the river valleys of the North and South Saskatchewan Rivers and the Qu'Appelle River. North Battleford obtains part of its supply from an alluvial aquifer which is recharged by the adjacent North Saskatchewan River (Lennox et al., 1988). Many of the surficial aquifers provide some of the best drinking water supplies in Saskatchewan for farm and other domestic uses; generally though, they are too small and too sensitive to drought to serve for larger or reliable supplies.

1.3 HYDROGEOLOGY OF THE CANADIAN SHIELD

The region north of a line drawn from Amisk Lake in the east to about latitude 57° 15' north in the west is part of the Canadian Precambrian Shield (Rump and Harper, 1980). The Shield consists of highly deformed metamorphic and igneous bedrock which in places is overlain by sedimentary basins. The major one such basin in northern Saskatchewan is the Athabasca sandstone basin which extends from Lake Athabasca in the north, beyond Cree Lake in the south, to Wollaston Lake in the east, and beyond the Saskatchewan-Alberta border in the west.

"Topographically this region is characterized by rock ridges separated by swamps, muskegs and lakes. The ridges seldom rise more than 60 m above the surrounding lake level except in the area north of Lake Athabasca where local relief is more rugged and the ridges are as high as 213 metres" (ibid.). The region is sparsely populated and most of the population relies on abundant surface water. The available information about hydrogeology comes mostly from mines which require dewatering and from information extrapolated from other parts of the Shield.

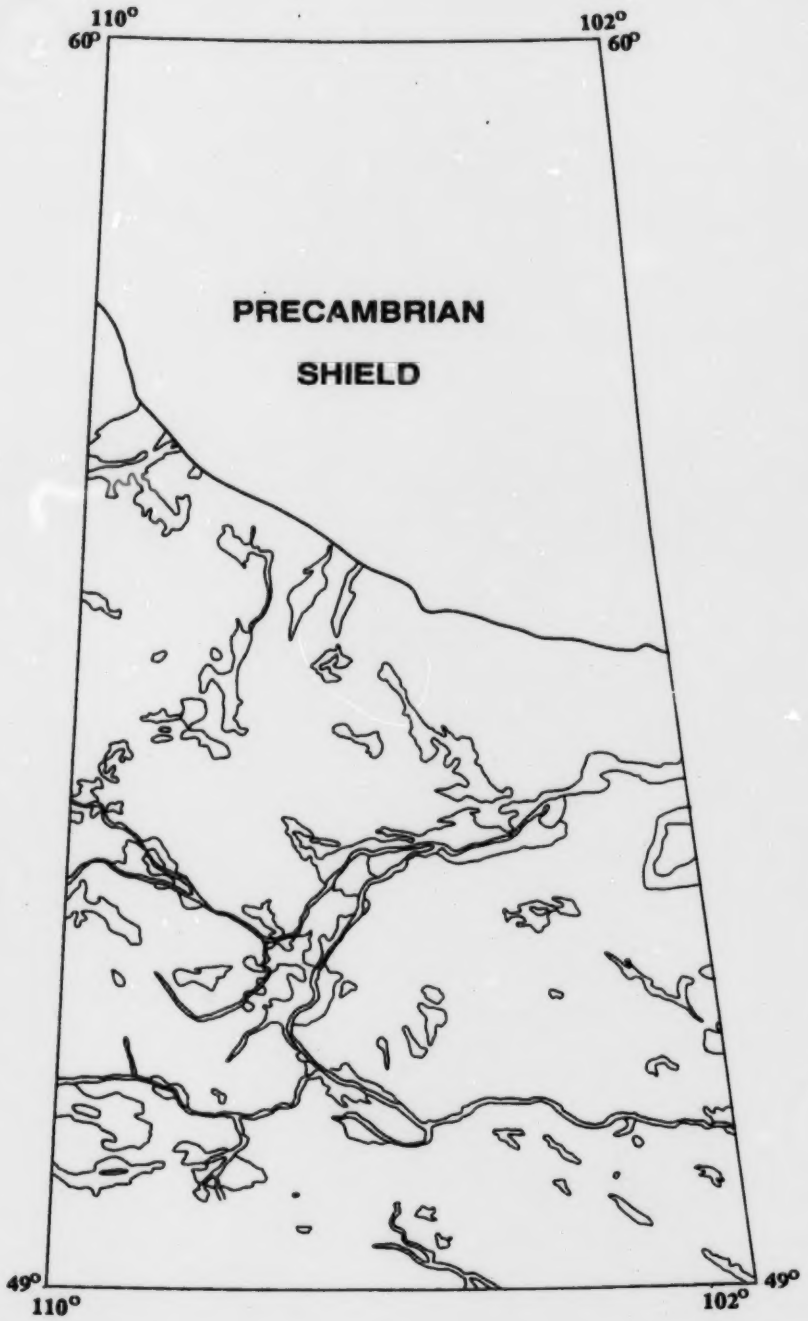

Figure 4. Location and extent of surficial aquifers (After Maathuis, 1990)

The metamorphic bedrock is generally massive and dense. Permeability is usually determined by fractures and faults which are not necessarily interconnected. Wide variations in geologic structure and composition can result in a variety of fracture patterns, some of which may be very localized. There are no known wells drilled in this type of rock in Saskatchewan and no demand for any in the foreseeable future. Experience from Ontario shows that such wells produce only enough water for domestic supplies except in rare locations where the rock is highly faulted and fractured (Ontario Ministry of Natural Resources, 1984).

Most areas of the Shield are covered only by thin intermixtures of sand, silt, and clay of glacial origin; these are interspersed with areas of organic deposits (swamps and bogs). In theory, eskers and shallow sandy and gravelly till in surficial deposits should provide good local water supplies. However, a large part of the Shield lies in a region of scattered or intermittent permafrost, and shallow groundwater may not be available or may only be available for part of the year while there is usually an ample supply of good quality surface water (Lane and Sykes, 1982).

1.4 WELL YIELDS

The majority of wells in Saskatchewan have low yields (less than 0.75 L/s). In an inventory done by the Saskatchewan Water Corporation, 59.4 percent of all wells had yields less than 0.75 L/s, and 21.2 percent had yields less than 0.075 L/s (Roeper, personal communication, 1988). It is likely that wells could give higher yields if they were designed and completed to meet larger demands. The highest yields can be expected from buried valley and blanket aquifers whose yields can exceed 50 L/s. Bedrock aquifers are expected to have yields between 0.5 and 5 L/s except in some parts of the Ravenscrag Formation where yields up to 55 L/s may be possible (Lane and Sykes, 1982).

Yields in the Athabasca Precambrian sandstone have been estimated from results from mine dewatering. Yields of 0.5 to 2 L/s have been estimated (MLM, 1979), but yields of 10 L/s are known. Even in this sandstone, overall permeability is primarily determined by the secondary permeability due to faults, joints and fractures.

1.5 GROUNDWATER QUALITY OF THE INTERIOR PLAINS

Except for groundwater in surficial aquifers, virtually all groundwater in southern Saskatchewan is of marginal quality. Most prairie groundwater fails to meet the Canadian Drinking Water Guidelines of 500 mg/L for total dissolved solids (TDS) and 500 mg/L for sulphate. Water with a higher content of TDS can be drunk without risk to human health (Health and Welfare Canada, 1987; CCREM, 1987), and this is recognized by the Saskatchewan drinking water quality guidelines (maximum desirable concentration for TDS in municipal drinking water is 1,500 mg/L; Saskatchewan Environment, 1980). Chloride concentrations in most of the aquifers used for municipal and domestic water supply are less than the recommended guidelines of 250 mg/L. Iron and manganese

concentrations, however, quite often exceed the recommended guidelines for municipal and domestic use (Maathuis, 1990). Water with more than 1,000 mg/L TDS should be evaluated in detail before being used for irrigation. Canadian water quality guidelines for livestock are 3,000 mg/L but some livestock can tolerate total dissolved solids up to approximately 7,000 mg/L (CCREM, 1987).

1.5.1 Groundwater Quality In Bedrock Aquifers

Groundwater in bedrock aquifers is of marginal quality. Total dissolved solids in groundwater from the Judith River Formation range from 1,300 to 8,000 mg/L but are generally less than 2,500 mg/L in the developed part of the aquifer (Kewen and Schneider, 1979; Whitaker, 1982). Water in the western part of the Ravenscrag aquifer contains around 1,000 mg/L TDS; water in the eastern part contains around 2,600 mg/L. Groundwater in deeper bedrock may contain up to 300,000 mg/L TDS (Maathuis, 1990) and is only suitable for such industrial use as enhanced oil recovery. The best quality of water in bedrock (around 500 mg/L TDS) is found in the Wood Mountain and Cypress Hills formations (Lane and Sykes, 1982).

1.5.2 Groundwater Quality In Quaternary Aquifers

The freshest water, often containing less than 1,000 mg/L TDS is found in surficial aquifers. The water quality in shallow intertill aquifers is highly variable and depends on the hydrogeological setting, recharge mechanism, and geochemical evolution of the water. Typically, water in such aquifers has TDS in the 1,500 to 3,000 mg/L range, and is hard and sulphate-rich. Iron and manganese often occur in concentrations which require treatment. Water in deep intertill, blanket, and buried valley aquifers shows water quality characteristics similar to those of bedrock aquifers (Maathuis, 1990).

1.6 GROUNDWATER QUALITY OF THE CANADIAN SHIELD

On the Shield, water quality in bedrock (unless taken from extreme depth) and in surficial deposits is generally good or very good (TDS less than 300 mg/L), significantly better than in most parts of the Interior Plains. Most waters will be the calcium-magnesium-bicarbonate type (Lane and Sykes, 1982). High concentrations of iron or manganese may also be found (Roeper, personal communication, 1988).

2. GROUNDWATER QUALITY CONCERNS

In Saskatchewan, 54 percent of the population (90 percent of the rural population) and over 80 percent of the municipalities depend on groundwater (Hess, 1986). (NOTE: Some municipalities included in this percentage may get part of their supply from surface water sources.) According to the latest estimates by the Saskatchewan Water Corporation, 50,000 wells are in operation in the province (Kaminsky, Sask Water, personal communication, 1990). Forty-four percent of all wells in use were thought to be less than 15 m deep (Walker and Partners, 1987). Shallow wells were thought to be common south of the 54th parallel but less common in the west (central and southwest).

Vulnerability of aquifers: The threat of groundwater contamination depends heavily on the type of aquifer. Most bedrock, buried valley, blanket or intertill aquifers are covered by thick aquitards of clay or till and are reasonably well protected from surface or near surface contamination; if threatened at all it is from deep-well injection or mining. Surficial aquifers, shallow intertill and shallow bedrock aquifers on the other hand, are exposed to the surface or are covered by a thin aquitard, and are easily contaminated by surface contaminants or underground storage facilities. The distribution and extent of such shallow aquifers has not been mapped or documented in the province at a regional level. It is known, however, that they occur widely in the south of the province, often serving as water supplies for farms and rural communities. The Saskatchewan Research Council has now begun to map these aquifers (SRC, 1988).

Sources of contamination: The sources of contamination of most concern in the province are spills, landfill sites, leaking gasoline storage tanks, and pathogens and nitrates in rural areas (from natural sources, septic tanks, fertilizers, feedlots, manure piles and storage lagoons). There is also concern about possible effects of deep-well disposal, the potential impact of mining (potash, uranium and coal) on groundwater, and the potential threat to shallow aquifers from agricultural chemicals (pesticides and fertilizers), especially in irrigated areas.

Naturally Occurring Compounds: Naturally occurring high salt levels in much of the prairie groundwater are also of concern. Sulphates or nitrates are found in many shallow aquifers. In some areas, one can also find groundwater containing hydrogen sulphide, iodides, uranium or radon. A serious problem which does not so much affect groundwater but where groundwater plays an important role, is the salinization of agricultural soils.

Areas of Concern: The area of greatest concern is the Regina area with its underlying aquifer system, which provides a significant percentage of the city's total water supply. There are other areas in the province where shallow aquifers underlying developed areas are used as water supplies. These areas might also be in need of integrated management (e.g. wellhead protection zones or integrated land use planning). Examples of such areas might be the Yorkton or the North Battleford areas where

municipal supplies are fed from relatively shallow (8 to 60 m) wells (Maathuis, 1990; Roeper, personal communication, 1988).

2.1 REGINA

The City of Regina obtains about 30 percent of its municipal water from groundwater (Roeper, personal communication, 1988). In the greater Regina area, two municipal landfill sites are located over the Regina aquifers or their recharge areas. These sites are being monitored and assessed; preliminary information suggests that landfill leachate may not affect the city's water supply. A new municipal landfill site for the City of Regina is currently being considered. There is also concern about the effects of planned relocation of the CN rail-yards to the recharge area of the Regina aquifer.

At one decommissioned industrial site, petrochemical wastes have contaminated underlying groundwater, though not the aquifer supplying Regina with drinking water; that site is still being assessed. In 1976, a spill of 7,000 to 21,000 L of oil composed primarily of PCBs and chlorobenzene, occurred in Regina. That spill and its effect on the aquifer have been intensely investigated (for a summary description see Cherry, 1987). While it was found that the contaminants had migrated (both vertically and laterally) in the fractured clay, it was concluded that "the aquifer is not, and very likely will not soon become, contaminated ". The most significant hazard was thought to be conduits which may be formed in the future by improperly constructed water wells on the site. It has been decided that there will not be any further well construction at the spill site (Chang, personal communication, 1987).

The concern has been expressed (Cherry, 1987) that difficult situations could arise in many areas of the prairies where aquifers are nominally protected by confining layers of silt or clay with deep open fractures. Any liquid spill, leachates from landfill sites, etc., may result in extensive but largely unpredictable migration of contaminants through these layers.

A site selection study for a new municipal landfill site for the City of Regina is currently (1990) underway. Steps are also being taken to include management and protection of groundwater resources into integrated land use management in the Regina area. Maps indicating sensitivity and vulnerability of groundwater resources and land use guidelines are being developed for the region.

2.2 LAND DISPOSAL SITES

Saskatchewan has a large number of land disposal sites. In a federal-provincial study in 1983, a total of 1,324 were identified. Of these, 958 were active and 366 were inactive or closed sites. Seventy-eight active and 19 inactive sites were designated category 1 sites: "sites which may exhibit a higher potential for impacts on human health and the surrounding environment" (Stewart, personal communication, 1988). A reduction

in the number of active sites has been recommended (Environment Canada, 1984) and some of the active sites are now being decommissioned. Several of the major sites identified in the study have monitoring wells. The site at the University of Saskatchewan has been excavated and the waste sent for secure disposal. No remediation is at present going on at any of the other sites, and no new sites have been identified since the original study.

2.3 UNDERGROUND STORAGE TANKS

Leaks in underground storage tanks present another situation where migration in fractured clay may become a source of concern. The province has at present (until the enactment of the Hazardous Substances Regulations and its provisions for tank registration, see Section 3.2.1.4) no data on the number and type of underground storage tanks. About 50 gasoline leaks and spills from storage tanks (including those from lines) occur every year (Chang, personal communication, 1987). It is not known how many of these affect groundwater.

2.4 BIOLOGICAL AND NITRATE CONTAMINATION

In most rural, intensely agricultural areas, nitrate contamination of groundwater may occur from septic tanks, feedlots, and sometimes from fertilizers and tilling practices (Cherry, 1987). In addition, septic tanks and feedlots may also cause biological (mainly bacterial) contamination. To what extent local contamination of soil or aquifers affects drinking water wells depends largely on the construction, maintenance and location of wells and septic tanks. Actual numbers on the extent and levels of well contamination from these sources are generally not known.

2.5 PROBLEMS RELATED TO AGRICULTURE

In Saskatchewan, potential problems related to agriculture and groundwater are soil salinization, nitrate contamination from tilling practices and fertilizers, contamination by nitrates and pathogens from feedlots and manure storage, and shallow aquifer contamination by pesticides. Some of these have already been mentioned in Section 2.4. Of all these, soil salinization of dry and irrigated lands is probably the most serious but also the most intractable problem.

2.5.1 Salinization

Salinization occurs when groundwater (or irrigation water) leaches salts from the subsurface in one area and carries them close to the surface elsewhere, often a low-lying discharge area. It is estimated that a few metres below surface, most agricultural soil in Saskatchewan is saline (van der Kamp, 1988) and that only a small change in the water balance is required to bring that salt to the surface (e.g. Keller and van der Kamp, 1988). Discharge, capillary action, or a rise in the water table brings the salts to the surface;

subsequently, evaporation increases the salt content of the soil. The salt then interferes with normal root growth and plant uptake of water and nutrients (Coote, 1983). It is a phenomenon only of arid to subhumid areas; i.e. all of the prairies. In Saskatchewan it is primarily a concern in grain-growing areas. Salinization occurs under natural conditions but may have increased as a result of anthropogenic changes in the regime of shallow groundwater (Coote, 1983).

2.5.1.1 Dry-Land Salinity

About 0.6 million hectares of agricultural soil in Saskatchewan are thought to be affected by dryland salinity (data from the Soil Landscape Mapping Project of Agriculture Canada, 1988). How much of it, though, is anthropogenically induced and by how much it has increased as a result of agricultural activities is a matter of dispute. In neighbouring Alberta and Montana the opinion prevails that dryland salinity has significantly increased over the last 20 to 30 years, presumably because of agricultural practices (Prairie Farm Rehabilitation Administration, 1983; Vander Pluym, personal communication, 1988). However several scientists in Saskatchewan believe that in this province the increase has not been pronounced (personal communications with L. Henry, 1988; D. Acton, 1988; and G. van der Kamp, 1988).

Most dryland saline seeps occur over a limited area (1 to 10 ha), sometimes close to the recharge area (about 2 km), sometimes as much as 20 to 30 km away. They almost always occur in an area of local or regional discharge (Coote, 1983; Prairie Farm Rehabilitation Administration, 1983). In some areas (Quill Lake, Yorkton, Last Mountain Lake) discharge is thought to occur through the aquitard above an artesian section of the Hatfield Valley aquifer (Henry, personal communication, 1988; van der Kamp, personal communication, 1988). Areas of saline soil are found primarily in the southern half of Saskatchewan (Coote, 1983). The extent often varies with precipitation; salinity increases after a series of wet years (ibid.).

The anthropogenic changes in shallow groundwater regimes which may exacerbate dryland salinity may be any activity which produces local accumulation of water (sloughs, ponds, or ditches); it may also be a rise in water tables caused by the replacement of natural grassland with annual grain crops (having shorter root systems) and the practice of summer fallow which increases the infiltration rate considerably (Coote, 1983; Prairie Farm Rehabilitation Administration, 1983). In some areas in the prairies, water tables have risen from about 3 to 4 metres below surface to 1 to 2 metres, and the extent of the partially saturated zone has increased as well (Vander Pluym, personal communication, 1988).

Dryland salinity related to cropping practices seems to appear around 35 to 40 years after an area is first cultivated, to increase rapidly over the first 20 years and then to slow down. It may eventually reach an equilibrium (Vander Pluym et al., 1981; Vander Pluym, personal communication, 1988; Coote, 1983).

2.5.1.2 Salinization of Irrigated Areas

Salinization of irrigated areas occurs when water tables rise from leaky irrigation canals, excessive irrigation, or groundwater discharge. It seems to appear about 10 years after irrigation is first started and it is estimated to affect about 15 to 25 percent of irrigated land in Saskatchewan (Coote, 1983). Most of the irrigated areas (in Saskatchewan only a small percentage of cropland) are found around Lake Diefenbaker (e.g. Outlook, Riverhurst, Luck Lake). In all, 123,000 hectares of agricultural land in Saskatchewan are irrigated (Weiterman, personal communication, 1988). It is thought that about 70 percent of salinization of irrigated areas is caused by seepage from irrigation canals, 20 percent by natural conditions and 10 percent by over-irrigation (Sommerfeldt and Rapp, 1977; Patterson and Harker, 1983).

2.5.1.3 Solonetzic Soils

A related problem is the presence of solonetzic soils; i.e. soils with high sodium content relative to calcium and magnesium. Such soils have probably been formed by saline groundwater (mostly from bedrock). Their high sodium content leads to the formation of a dense, almost impermeable layer close to the surface ("hardpan") which interferes with plant growth and drainage (Coote, 1983; PFRA, 1983; Acton, personal communication, 1988). About 2 to 3 million hectares of solonetzic soil are found in Saskatchewan (ibid.).

2.5.2 Feedlots

Studies done in Alberta on the effect of feedlots on groundwater (Sommerfeldt et al., 1973; Bennett and Graveland, 1976) have shown that the soil on the feedlot itself becomes virtually impermeable to infiltration. Contaminated runoff water may pose a threat to groundwater.

2.5.3 Pesticides

While agricultural chemicals are extensively used in the province, the low amount of precipitation and recharge will likely limit any contamination of shallow groundwater. In many cases there may not be sufficient infiltration after an application of pesticides in the spring or summer to transport them to the water table. Irrigated areas may be an exception. Nevertheless, the extensive use of pesticides in the province (as in the rest of the prairies) makes it important to definitely resolve the question whether they affect groundwater or not.

A detailed list of commonly used pesticides in the prairies was produced by Environment Canada (Western and Northern Region) and includes triallate, 2,4-D, trifluralin, MCPA, diclofop-methyl, bromoxynil, pentachlorophenol, trichloroacetic acid (TCA), dicamba, glyphosate and lindane (Constable, personal communication, 1988).

Frequently used insecticides are carbofuran, carbaryl, dimethoate, deltamethrin (aerial application) and chlorpyrifos. Some of the highly soluble urea herbicides (e.g. chlorsulfuron Glean) may also be of concern because of the difficulty of detecting them at the low levels used.

To date, little conclusive evidence for or against contamination of shallow groundwater by pesticides has been found. In a careful study by the Saskatchewan Research Council, Environment Canada (NHRI) and the Regina Research Station of Agriculture Canada (Maathuis et al., 1988; McNaughton, personal communication, 1989), the potential for aquifer contamination in an irrigated area at Outlook was investigated. Groundwater was tested for dicamba, MCPA, diclofop-methyl, triallate, trifluralin, bromoxynil, and 2,4-D. Only a few detections at very low (tenths of ppb), transient or poorly reproducible levels were registered. NHRI, in collaboration with the Regina Research Station of Agriculture Canada, is now studying pesticides (diclofop-methyl, triallate, 2,4-D) in fractured clay close to a slough in a dryland farming area near Regina following a report of potential contamination (Waite, Environment Canada, Regina, personal communication, 1988).

The pesticide container disposal program (see Section 5.6) may have considerably reduced the threat to groundwater from the disposal of containers. An investigation conducted in 1986 found that these sites (there are about 250 of them) would not cause contamination if properly operated and maintained (Chang, personal communication, 1987).

2.5.4 Fertilizers and Tillage

Some nitrate in shallow groundwater may be derived from fertilizers or from the oxidation of organic nitrogen in soil, especially after tillage and increased aeration (Freeze and Cherry, 1979). Hendry et al. (1984) have found evidence that in Alberta, most of the high nitrate concentration in shallow groundwater has older (3,000 to 10,000 years) natural origins. No such evidence is available for Saskatchewan, and human influences (oxidation of organic nitrate when the soil was first broken for tillage) may have played a larger role. The semi-arid conditions in much of the prairies likely make fertilizers a minor source of nitrate, although contamination by sewage, manure or fertilizers is locally significant.

2.6 DEEP-WELL INJECTION

Deep-well disposal, its safe operation and the possible need for regulation is another concern in Saskatchewan. During 1984, about 50 million m^3 of brine, some from potash mining but most from petroleum production, were injected at about 1,100 wells (Bernier, personal communication, 1988). Most of these wells are used for secondary oil recovery whereby brine is injected into the formation from which the oil came. At present (1989) 19 wells are used for the disposal of brine from the potash industry, and one well is

being used for disposal of refinery waste. About 10 deep wells (storage cavern wells) are used to pump brine in and out of salt storage caverns to manipulate the stored contents, but that brine is not injected under pressure. In the 1960's and 1970's, up to 11 wells were used for chemical and potash waste disposal, and a total of about 650,000 m^3 of waste were injected (Van Everdingen and Freeze, 1971; Dennison and Simpson, 1973; Simpson and Dennison, 1975; Eco/Log Week, 1980). Recent approval was given to allow injection of refinery/upgrader wastes, only after having the strictest requirement to date imposed on the project by the environmental impact statement. In 1986, a study prepared for the Saskatchewan Department of Environment stated that deep-well injection may be acceptable in some areas of Saskatchewan which have been designated as having acceptable hydrology (M.M.Dillon Ltd, 1986).

All deep-well injection is controlled by Saskatchewan Energy and Mines (see Sections 3.2.5 and 4.4); Saskatchewan Environment and Public Safety and the Saskatchewan Water Corporation also play a regulatory role if such injection either has the potential to affect the environment (e.g. waste injection) or water resources (see Section 3.2.1 and, for an overview of policy, see Section 5.7). Saskatchewan Environment and Public Safety permits deep-well injection of liquid waste from the mining industry, provided the following requirements are met:

i) the liquid is the same type that already exists in the deposit formation; and

ii) approval is granted by Saskatchewan Energy and Mines.

If the liquid waste contains constituents foreign to the disposal formation, an environmental impact assessment must first be carried out in accordance with the Environmental Assessment Act. If the assessment is favourable, a permit may be issued by Saskatchewan Environment to allow for the disposal of the waste by deep-well injection (Bernier, personal communication, 1988).

2.7 MINING

Potash, uranium, and coal are the main resources mined in Saskatchewan. Potential sources for the contamination of ground- and surface water are brine ponds, tailings ponds, tailings piles, and waste rock piles. In mining areas, groundwater is often more of a concern as a pathway for contaminants to surface water than as a threatened resource. For example, any brine escaping from potash mining in the Rocanville area may quickly end up in the Qu'Appelle River. Abandoned mines and the ultimate disposal of tailings are seen as the main problems. In contrast, seepage and effluent discharges from operating or recently closed mines are tightly controlled and regularly monitored. All mining operations have seepage control systems as part of their waste management facilities. The main concerns, all relating to long-term disposal, are:

i) control of brines and the ultimate disposal of salt tailings in the potash industry;

ii) control of tailings seepage from abandoned uranium mines in northern Saskatchewan (one of which contains tailings with sulphur content high enough to produce acid drainage); and

iii) control of radionuclides and other elements (Ni, As) after eventual closure of currently operating mines.

Concern has been expressed about contamination by boron or uranium from coal mining in southern Saskatchewan. Levels in coal and in dewatering water, however, are generally too low to have significant environmental effects on ground- or surface water (Poplar River Bilateral Monitoring Committee, 1988) even though coal from the Cypress Hills coal fields contains relatively high uranium values; i.e. up to 700 mg/kg compared to the generally less than 5 mg/kg at Poplar River (Cameron and Birmingham, 1970). Only in ash from coal-fired generating stations may these elements become concentrated to higher levels.

2.8 OTHER CONCERNS

Uranium and other trace metals in coal are concentrated in the ash of coal-fired power stations. Seepage of these elements from ash lagoons is then a potential threat. Because of potential international implications, groundwater, surface water, and wastewater at one power station near the U.S.-Canadian border (Poplar River) have been particularly closely monitored by the Poplar River Bilateral Monitoring Committee. The focus of the concern is for water quality in the East Poplar River (which flows into Montana about 10 km from the power station) and anything that may affect such quality (e.g. seepage or outflow from ash lagoons). All recorded uranium values in the Poplar River have been low; i.e. 2.8 0.8 µg/L (Baweja et al., 1987). [The Canadian Drinking Water Quality Guidelines allow a Maximum Acceptable Concentration of 20 µg/L (Health and Welfare Canada, 1987; CCREM, 1987)]. No significant seepage seems to have occurred from any ash lagoons, although it is difficult to monitor seepage because of some high natural uranium content (up to 1200 µg/L) in groundwater surrounding the lagoons.

2.9 NATURAL CONSTITUENTS

Groundwater which contains relatively high, natural levels of chlorides, sulphates, carbonates, or nitrates, is commonly found in Saskatchewan. With the exception of some surficial and some other shallow aquifers and the groundwater of the Canadian Shield, the limits recommended by the Canadian Water Quality guidelines (500 mg/L for total dissolved solids and 250 mg/L for sulphate) are commonly exceeded (Lennox et al., 1988). More mineralized water may be drunk without risk to human health and, depending on species, some livestock can tolerate total dissolved solids up to 7,000 mg/L. The main restriction is on irrigation water which, if its TDS exceeds 1,000 mg/L, should be further investigated (CCREM, 1987).

2.9.1 Sulphates and Nitrates

While chloride concentrations increase with depth, sulphate from oxidation of pyrite and nitrate from organic nitrogen and ammonium compounds are formed in the unsaturated zone and found in shallow groundwater (Hendry et al., 1984; Keller and van der Kamp, 1988); some sulphate is also transported from deeper groundwater into shallower groundwater (Hendry et al., 1986). Concentrations of sulphate as high as 1,500 mg/L and, in isolated cases, 100 mg/L of nitrate have been found in shallow groundwater (Maathuis, 1990). It is difficult to differentiate between anthropogenic (sewage, manure, fertilizer, tillage) and natural causes of high nitrate in shallow groundwater, although special (isotope) techniques sometimes allow such differentiation. In many cases, nitrate in shallow groundwater decreases rapidly with depth below the water table as denitrification occurs (Trudell et al., 1986).

2.9.2 Other Compounds and Elements

Elevated concentrations of iron and manganese may be found in wells all across the province. Iodide concentrations up to 5 mg/L have been found in bedrock aquifers, mostly in conjunction with high chloride concentrations; e.g. in the Riverhurst area. In some areas, particularly in the oil-producing districts, hydrogen sulphide and hydrocarbon gases have been detected in water wells. In some parts of the province (e.g. one wellfield near Regina) one can also find elevated arsenic concentrations (Roeper, personal communication, 1988).

Uranium and radium are found in many areas in the south, particularly in the Ravenscrag Formation. Concentrations between 0.8 and 39 µg/L were found in wells in southwestern Saskatchewan (Dyck et al., 1976). Groundwater in and around the coal seams of southern Saskatchewan (e.g. Cypress Hills) also contains uranium. Elevated levels of radon have been found in houses located over the Ravenscrag formation (10 houses or 1.6 percent of those checked with concentrations of radon daughters above 0.1 WL), and north of the 54th parallel (especially La Ronge) (Sentis and Wagner, 1985; Letourneau et al., 1984). Radon is a greater concern as a contaminant of indoor air than as a contaminant in drinking water. Tap water from groundwater may be a medium of transport into indoor air (Cherry, 1987) though only in rare circumstances is it thought to be a significant factor. A level of 10,000 Bq/L radon in household water typically results in an increase of radon in indoor air of approximately one Bq/L (Becker and Lachajczyk, 1984) and it appears that in most cases elevated radon concentrations in tap water lead only to short-term elevated concentrations in bathroom air during showers (McGregor and Gourgon, 1980). A fluctuating water table may also play a role as a "suction" effect during the movement of radon between the subsurface and the interior of a house (LeGrand, 1987). Saskatchewan Environment and Public Safety (Mines Branch) has produced the publication "Preliminary Index Map of Radon Problem Areas in Northern Saskatchewan" (Sentis and Wagner, 1985).

3. GROUNDWATER MANAGEMENT - LEGISLATIVE INSTRUMENTS

3.1 WATER RESOURCES LEGISLATION

3.1.1 The Water Corporation Act

This Act supports the following functions:

i) establishing the Saskatchewan Water Corporation (Sask Water) and giving the Corporation the power and responsibility to manage water and related land resources in Saskatchewan;

ii) vesting of ownership of all water (surface and groundwater) in the Crown;

iii) authorizing any withdrawal, use, or diversion of water (except for domestic use); and

iv) approving, by the Water Corporation and the Minister of the Environment, all drainage, sewage, and water works.

3.1.2 The Groundwater Conservation Act

This Act requires:

i) well drillers to notify the Saskatchewan Water Corporation before drilling and to provide well records (and electric logs if such were done) to the Water Corporation; in principle, data for all wells (drilled, dug, or jetted) have to be provided;

ii) registration of all well drilling equipment;

iii) wells to be constructed to prevent contamination;

iv) closing of abandoned wells and test holes;

v) licensing for all but domestic wells; and

vi) the issuance of permits for groundwater investigations.

3.2 WATER QUALITY LEGISLATION

3.2.1 The Environmental Management and Protection (EMP) Act

The Act gives the Minister of the Environment wide-ranging powers to issue orders to investigate any activities which may pollute the environment, to monitor for effects, to halt such activities, and to restore the affected environment.

3.2.1.1 Water Pollution Control and Waterworks Regulations

These regulations control the discharge of effluents to the environment (effluent limits are site-specific as determined by environmental impact assessment). There are also water quality objectives which are being revised on the basis of the new Canadian Water Quality Guidelines.

3.2.1.2 Municipal Refuse Management Regulation

This regulation requires municipalities to obtain approvals to establish municipal refuse disposal grounds (landfills). The regulations stipulate site-specific investigations and characterization of hydrogeology and associated land use in addition to operational standards. General guidelines are being discussed.

Measures specifically directed towards the protection of groundwater are:

i) information specifically related to groundwater protection is required as part of the approval process;

ii) the Minister may impose conditions when issuing the permit; for larger sites, groundwater monitoring around the site may be one of the conditions; and

iii) certain categories of waste, some of which may pose a threat to groundwater, are not permitted at municipal sites.

3.2.1.3 Environmental Spill Control Regulation

This regulation requires the reporting of spills to Saskatchewan Environment and Public Safety. The regulations also require responsible remedial action and disposal of contaminated materials resulting from a spill.

3.2.1.4 Hazardous Substances Regulations

These regulations control the use, storage and handling of a wide range of hazardous substances, including petroleum products located at storage facilities, in underground tanks, in above ground tanks or in warehouses. The regulations require the

registration of storage facilities, inventory control, leak monitoring, contingency planning and adherence to specific construction standards.

3.2.1.5 Industrial and Hazardous Waste Management Regulations

These regulations are in a late draft stage (4th draft as of November, 1990). They are intended to regulate generation, transport, storage, treatment and disposal of hazardous waste. The regulations will provide lists and criteria for handling of different types of hazardous waste with provisions for a few hundred substances.

3.2.1.6 Mineral Industry Pollution Prevention Regulations

These regulations require approvals to discharge wastes from mining operations, and require reclamation and approval to abandon areas disturbed by mining.

Approvals specify conditions which limit discharges, and require studies, monitoring (including groundwater), and may require remedial action. Lands disturbed by mining cannot be abandoned without provisions for long-term protection of air and water quality.

A new draft of the regulations, intended to strengthen environmental control of the mining industry, is expected to be promulgated in the Spring, 1991. It will require approval for construction, operation (annual), decommissioning, and abandoning of any mineral development. Specific requirements or standards are also included.

The regulations are administered by the Mines Pollution Control Branch of Saskatchewan Environment and Public Safety. At present, initial environmental impact assessments under the Environmental Assessment Act are required before a mine can be opened, and annual permits are required by the Department of Environment and Public Safety under the EMP Act.

3.2.2 The Environmental Assessment Act

The Environmental Assessment Act requires environmental impact assessments for all developments (projects, operations, or activities) or their extensions. The assessment of such developments is based on six specific criteria:

i) effect on a rare or endangered feature of the environment;

ii) substantial utilization of a provincial resource in a way which preempts the use of that resource;

iii) emission of pollutants not regulated by other means;

iv) cause of wide-spread public concern;

v) introduction of a new technology not previously assessed; and

vi) significant effect on the environment, or requirement for further action with significant effect on the environment.

The proponents are responsible for the assessments. Recommendations resulting from the assessments are forwarded to the Minister of Environment and Public Safety. The Act is administered by the Environmental Assessment Branch of Saskatchewan Environment and Public Safety under whose coordination interdepartmental review panels are convened to review the assessments and submit recommendations to the Minister whose decision is binding.

3.2.3 The Department of the Environment Act

This Act gives the Department of Environment and Public Safety a mandate not only to protect the quality of the environment but also to administer the water quality and other environmental legislation under the EMP Act (Section 3.2.1).

3.2.4 The Public Health Act

This Act gives the Department of Health some responsibility for small water and sewage systems (less than 18 m^3 per day and not municipal) not addressed by legislation administered by the Department of Environment and Public Safety.

Part of the Act is the Plumbing Regulation and the Shoreline Pollution Regulation, which regulate the construction and operation of private sewage disposal systems. CSA standards are required, permits have to be obtained, and systems have to be inspected before operation.

3.2.5 The Oil and Gas Conservation Act

Under this Act licences are required before any deep-injection well may be drilled. Geological and completion information, and the approval of the Minister of Energy and Mines are required before operation of the well commences. During operation, yearly pressure tests are required.

For any eventual waste injection, approval by Saskatchewan Environment and Public Safety under the general provisions of the EMP Act (Section 3.2.1) are also required.

3.2.6 Other Acts and Regulations with Potential Bearing on Groundwater Quality

Federal legislation such as the Pest Control Products Act through its control over pesticide use, and the Dangerous Goods Transportation Act through its control of transportation practices where spills are more likely to occur, have an indirect effect on groundwater quality and may also be specifically directed toward the protection of groundwater quality in certain situations.

4. GROUNDWATER MANAGEMENT - INSTITUTIONAL INSTRUMENTS

Saskatchewan has five agencies responsible for different aspects of groundwater management; in addition there is a research agency (Saskatchewan Research Council) and the Prairie Farm Rehabilitation Administration which, though a federal organization, plays an important role in Saskatchewan's rural groundwater management and collaborates closely with provincial agencies. The agencies and their principal roles are outlined in the table below, and further discussed in the remainder of this section:

Agency	Main Areas of Responsibility
Saskatchewan Water Corporation (Sask Water)	created to provide integrated water management for the province; responsible for water resources
Saskatchewan Environment and Public Safety	most aspects of water quality
Saskatchewan Public Health	some aspects of drinking water and health
Saskatchewan Energy and Mines	many aspects of deep-well injection
Prairie Provinces Water Board	interprovincial water issues
Saskatchewan Research Council (SRC) agencies, investigations	technical support for regulatory groundwater research, related to groundwater management
Prairie Farm Rehabilitation Administration (PFRA)	farm well construction, farm water supply (in collaboration with provincial agencies)

Formal collaboration occurs mostly through the dual approval system mandated by legislation (administered by Sask Water and Saskatchewan Environment and Public Safety) and the interdepartmental environmental impact assessment (coordinated by Saskatchewan Environment and Public Safety). In addition, SRC and Sask Water jointly operate one database; other databases maintained by various agencies are accessible by other agencies and are used by them in support of resource management. Some research activities (e.g. SRC's study of the Regina aquifer) are also designed to complement and support resource management (e.g. Sask Water's aquifer management plans). Agencies

involved in water management and research are generally decentralized (e.g. Regina, Saskatoon, Moose Jaw, Prince Albert).

4.1 SASKATCHEWAN WATER CORPORATION (SASK WATER)

The Corporation is responsible for water resource management. It has the authority to approve all drainage, water, and sewer works, all water diversions and dams, and all other activities which affect water quantities (e.g. mining, deep well disposal). In many cases, approvals from the Water Corporation and Saskatchewan Environment and Public Safety are required. In addition, it provides for cost sharing agreements for municipal water and sewer works, gives technical assistance, collects water resource data and, specifically for groundwater management, develops aquifer resource evaluations and aquifer management plans.

Most of these tasks are divided between the Resource Management and Operations Divisions of the Water Corporation.

4.1.1 Water Management Division

This Division is responsible for provincial collection of groundwater and surface water data, water resource planning, engineering, and groundwater and surface water technical support to the regional offices. This Division includes the Groundwater Hydrology Section. Development and implementation of management plans for important aquifers in Saskatchewan is a prominent activity of the Section.

4.1.2 Operations Division

This Division has six regional offices and two branch offices from where it deals with its responsibilities. In relation to groundwater management they are:

i) approval of water use (including irrigation);

ii) licensing of Water Rights projects; and

iii) grants, supervision and inspection, and assistance with well problems, etc.

4.2 SASKATCHEWAN ENVIRONMENT AND PUBLIC SAFETY

This Department is the main agency responsible for protecting water quality and other aspects of the environment from pollutants. The main legislative tools are the Environmental Management and Protection Act, the Environmental Assessment Act, and the Department of the Environment Act. As mentioned previously, dual approval of major projects (by Saskatchewan Environment and Public Safety and by Sask Water) is often required.

The main groups in Saskatchewan Environment and Public Safety responsible for groundwater protection are the Water Quality Branch, the Air and Land Protection Branch, the Environmental Assessment Branch, the Mines Pollution Control Branch, and the Office of the Fire Commissioner.

4.2.1 Water Quality Branch

The Water Quality Branch is responsible for:

i) water quality monitoring;

ii) monitoring drinking water quality of all municipal and those non-municipal water systems which have daily withdrawal of more than 18 m^3 a day;

iii) development of water quality objectives;

iv) control of regulated and unauthorized discharges of pollutants to water; and

v) maintenance of water quality databases.

The regional offices of this Branch are also concerned with sewage and drinking water systems, and with industrial effluents.

4.2.2 Air and Land Protection Branch

This branch has responsibilities relating to groundwater protection, including:

i) spill response and remedial action under the Environmental Spill Control Regulations;

ii) administration of the Hazardous Substances Regulations for chemical storage, e.g. petroleum storage tanks;

iii) administration of the Municipal Refuse Management Regulation, e.g. municipal landfill sites;

iv) administration of the Dangerous Goods Transportation Act (Sask.) for hazardous wastes;

v) administration of the Pesticide Container Disposal Program;

vi) regulation of the disposal of liquid domestic wastes;

vii) development and review of sewage sludge disposal guidelines; and

viii) promotion of reduction, recovery, reuse and recycling of industrial wastes.

4.2.3 Environmental Assessment Branch

The Environmental Assessment Branch is responsible for environmental impact assessments under the Environmental Assessment Act. Such assessments are mandatory for all major developments. Examples of developments for which such assessments may be required are industrial or residential developments, mines, power plants, very large landfill sites, large irrigation projects, deep-well disposal, etc. The proponent has to prepare the assessment. The Branch is then responsible for the coordination of the review and recommendation to the Minister. Interdepartmental review panels are convened under the coordination of the Branch and recommendations are forwarded to the Minister of the Environment and Public Safety.

4.2.4 Mines Pollution Control Branch

The Mines Pollution Control Branch is responsible for all environmental effects of mining (mainly uranium, coal, potash). It develops relevant regulations, issues annual approvals for mine operations, develops conditions for permissible operation and closure, and conducts regular inspections of mining operations.

4.3 SASKATCHEWAN HEALTH

4.3.1 Community Health Services Branch

The Community Health Services Branch is responsible for non-municipal public water systems with less than 18 m^3 of daily flow, and for standards for construction and operation of private septic tanks. Permits are required for septic systems which have to be inspected before operation. Approximately 41 provincial health inspectors inspect private sewage disposal systems and the public water systems for which the Department is responsible. Problems of chemical contamination and sampling for chemical contamination are usually dealt with by the Department of Environment and Public Safety, whereas health problems are dealt with by the Department of Health. In Saskatoon and Regina, municipal health inspectors carry out inspections; federal inspectors are responsible at federal facilities.

4.3.2 Northern Health Services Branch

This organization carries out duties in Northern Saskatchewan similar to those provided by the Community Health Services Branch in the southern part of the province (4 inspectors).

4.3.3 Public Health Laboratory

The Public Health Laboratory in Regina is one of the two provincial laboratories in Saskatchewan which provide water analyses. The laboratory will perform standard chemical, microbiological and trihalomethane analyses.

4.4 SASKATCHEWAN ENERGY AND MINES

4.4.1 Petroleum and Natural Gas Division

The Petroleum and Natural Gas Division enforces the provisions of the Oil and Gas Conservation Act. Of interest for groundwater protection are those provisions relating to deep-well injection (see Section 3.2.5). The Division issues licences to drill and minister's approval for operation on the basis of required geological and completion information. Personnel in the four field offices of the Division will also supervise the yearly required pressure tests at deep-well injection sites.

4.5 SASKATCHEWAN RESEARCH COUNCIL

4.5.1 Sedimentary Resources Program

The Saskatchewan Research Council maintains a network of water level monitors and collects groundwater quality data. It also designs and maintains databases for groundwater quantity data and carries out research projects on particular aspects of groundwater quality or quantity (e.g. pesticides in groundwater, salt tailings and their effect on groundwater, groundwater flow in glacial tills, hydrographs and aquifer evaluation). The Council collaborates closely with the Saskatchewan Water Corporation, especially on databases and mapping, and from time to time with the National Hydrology Research Institute of Environment Canada in Saskatoon. The Saskatchewan Research Council primarily carries out independent research.

The laboratory of the Saskatchewan Research Council is one of the two provincial laboratories which will provide water analyses.

4.6 PRAIRIE FARM REHABILITATION ADMINISTRATION (PFRA)

The Prairie Farm Rehabilitation Administration (PFRA), an arm of Agriculture Canada, provides financial and technical assistance for the construction of dugouts, farm-wells, dams to collect stock water, reservoirs, water supply pipelines and rural irrigation projects in all three prairie provinces.

PFRA adjusts its operation to that of an individual province. In Saskatchewan the agency uses its own technical, investigative group and, in specific instances, provides technical data to Sask Water. PFRA has assisted in the installation of 23,000 wells for individual farmers, groups of farmers, and rural communities in Saskatchewan. All

documentation on wells and aquifers is passed on to the Saskatchewan Water Corporation.

4.7 PRAIRIE PROVINCES WATER BOARD

The Board administers the Master Agreement on Apportionment for eastward flowing prairie rivers. It is composed of officials of the three prairie governments and the federal government (Prairie Farm Rehabilitation Administration and Environment Canada). It has a Committee on Groundwater which meets twice a year and makes recommendations on groundwater issues along interprovincial boundaries. The Committee has, through consultants, prepared hydrogeologic profiles of the Alberta/Saskatchewan and Manitoba/Saskatchewan boundaries.

5. GROUNDWATER MANAGEMENT - OTHER INSTRUMENTS

The special programs or instruments described in this section are:

1. Monitoring Programs
2. Mapping, Aquifer Management Plans, Aquifer Resource Evaluation
3. Data Collection
4. Technical Assistance
5. Financial Assistance
6. The Pesticide Container Disposal Program
7. Land Disposal Site Programs
8. Deep-Well Disposal
9. Water Quality Objectives
10. Laboratories Available for Groundwater and Surface Water Analyses.

5.1 MONITORING

5.1.1 Water Level Monitoring

The Saskatchewan Research Council maintains 50 automatic continuous water level recorders across southern Saskatchewan. In addition, the Saskatchewan Water Corporation uses water level monitors at specific locations for specific projects (e.g. mines); the latter are stand-pipes which are monitored when required.

5.1.2 Water Quality Monitoring

Baseline water quality at the 50 water level monitors operated by SRC is determined every 5 years (major ions, Fe, Mn, NO_3, SO_4, TDS, etc.). In addition, approximately 4,000 groundwater quality samples have been collected by SRC, mostly from farm wells with some data from test or observation wells. SRC's routine analyses include Ca, Mg, Na, Fe, Mn, CO_3, HCO_3, SO_4, Cl, NO_3, PO_4, F, pH, sum of ions, total alkalinity, and total hardness. (In these samples there are very few, if any, data on pesticides or other organic chemicals.)

5.1.3 Pesticide Monitoring in Irrigated Areas

The Saskatchewan Research Council, in collaboration with the National Hydrology Research Institute (NHRI), has studied the occurrence of pesticides in a small aquifer used by the town of Nokomis. The two research organizations and the Regina Research Station of Agriculture Canada have also studied the occurrence of herbicides in shallow groundwater beneath three irrigated sites in the Outlook area. This study is supported by the federal pesticides fund.

5.1.4 Pesticide Monitoring at Public Water Supplies and Farm Wells

From Summer 1985 to 1987, Agriculture Canada, in coordination with the provincial governments and other federal departments, monitored public water supplies for pesticides all across Canada. In Saskatchewan, 50 public water supplies per year have been monitored for phenoxyaliphatic acids or phenol derivatives or carbamates. In Summer 1988, the department monitored 50 private wells for glyphosate, trifluralin, triallate, phenol derivatives (bromoxynil, pentachlorophenol), and phenoxyaliphatic acids (2,4,-D, 2,4-DB, diclofop-methyl, MCPA and picloram).

5.1.5 Monitoring Connected to Major Developments and Environmental Impact Assessment

Monitoring for water levels, drawdowns, and groundwater quality are sometimes a condition for approval of major developments; e.g. at mining sites. Initial (and sometimes annual) approvals are required from the Saskatchewan Water Corporation or from Saskatchewan Environment and Public Safety or from both.

5.1.6 Site Specific Regulatory Monitoring

This type of monitoring is carried out as, and when, required by Saskatchewan Environment and Public Safety (Water Quality Branch). Examples are the Poplar River thermal power generating facility, a contaminated rail car cleaning facility in Moose Jaw, municipal and industrial landfill sites and municipal sewage lagoons. Wells and piezometers have been installed at many of the sites to satisfy requirements for operating permits which have been issued to project proponents. In these cases the proponent generally collects the data, may provide some interpretation and submits it to Saskatchewan Environment and Public Safety. In other cases monitoring is conducted by the province for suspected occurrences of groundwater contamination from spills, industrial and municipal landfills, sewage lagoons, etc. In 1990 groundwater quality data were collected from 111 piezometers in the province.

5.1.7 Drinking Water Monitoring at Public Water Supplies

Municipal supplies and non-municipal wells with flow rates over 18 m^3 a day are monitored as required by Saskatchewan Environment and Public Safety (Water Quality Branch). Saskatchewan Health (Public Health Inspection) monitors small non-municipal

wells. All new municipal supplies have to be sampled initially; thereafter, they are monitored at regular intervals by the municipality.

5.2 MAPPING, AQUIFER MANAGEMENT PLANS, AQUIFER RESOURCE EVALUATION

Hydrogeologic mapping is primarily carried out by the Saskatchewan Research Council. The Saskatchewan Water Corporation will concern itself with resource evaluation and aquifer management, often using maps and other hydrogeologic information produced or collected by SRC.

5.2.1 Hydrogeologic Maps of Bedrock Aquifers

The Saskatchewan Research Council has produced a series of geology and groundwater resource maps for southern Saskatchewan. They were produced in the 1960's and 1970's, mostly under ARDA (Agricultural Rehabilitation and Development Agreements). Geologic maps for all of Saskatchewan are available from SRC or from Saskatchewan Energy and Mines.

5.2.2 Multilayer (Bedrock and Unconsolidated Material) Hydrogeologic Maps

SRC is in the process of producing detailed multi-layer (bedrock and Quaternary aquifers) hydrogeologic maps for Saskatchewan. Preliminary maps have been produced for several National Topographic Series map sheet areas (e.g. North Battleford, Melfort). It is planned that final maps will contain data on yield, flow direction, velocity, water quality, etc.

5.2.3 Aquifer Resource Evaluation

The Saskatchewan Water Corporation did a series of "aquifer resource evaluations" for major (regional) aquifers, usually through consultants. In these reports, production potential, water quality, drilling depths of wells, etc., are given. The reports could form the basis for aquifer management plans; unfortunately zones of major groundwater production are often in smaller, more local aquifers for which aquifer resource evaluations are not available.

5.2.4 Aquifer Management Plans

The Saskatchewan Water Corporation has begun to develop "aquifer management plans" for intensely used regions. They will contain information on production potential, quality, location of sources of pollution, sensitivity of aquifers, required protection, and recommended development strategies. The plan for the Regina aquifer was completed in 1989. The Regina Groundwater Technical Committee (consisting of Sask Water, Sask Environment and Public Safety, the City of Regina, and SRC) has been formed to facilitate

exchange of information and to coordinate studies and monitoring activities. Work on the Yorkton aquifer management plan is currently (Spring, 1991) in progress and a proposal for the development of a southeast (i.e. Estevan/Weyburn) management plan is under review.

5.2.5 Hydrogeologic Maps of Interprovincial Border Areas

The Prairie Provinces Water Board has prepared, through consultants, hydrogeologic profiles of the Alberta/Saskatchewan boundary and of the Saskatchewan/Manitoba boundary. These profiles extend north from the U.S. border almost to the edge of the Canadian Shield, 19 km on each side of the interprovincial boundaries. They include relevant geology, principal aquifers, bedrock topography, effective base of groundwater exploration, and data control.

5.3 DATA COLLECTION

5.3.1 Data Collection by the Saskatchewan Water Corporation

The Saskatchewan Water Corporation keeps the following records:

i) computerized records of 83,000 well drillers reports (about 2,500 records per year are collected);

ii) electric logs from over 10,000 holes (about 600/year from well drillers); a second copy of this database resides with SRC;

iii) computerized records of licensed municipal and industrial water rights in the province;

iv) a library of engineering reports; and

v) production data of industrial groundwater supplies.

5.3.2 Data Collection by the Saskatchewan Research Council

The Saskatchewan Research Council keeps:

i) a database of water level data from the continuous water recorders and intermittent data from piezometers - often project-oriented - in specific areas;

ii) a database of the original electric logs reported to the Saskatchewan Water Corporation; reductions of these electric logs are on file at both Sask Water and SRC;

iii) computerized water quality records of approximately 4,000 wells; the records contain the conventional water quality parameters. The data are mostly from farm wells with some data from observation wells; almost all data are from SRC's own data collection, with selected outside data; and

iv) data from the 1960's on about 2,000 wells and some 1930's data (Rutherford, 1966). These data are not yet computerized and are being evaluated for quality and compatibility with the computerized data.

5.3.3 Data Collection by Saskatchewan Environment and Public Safety

The Water Quality Branch maintains databases on water quality of public water supplies and major water bodies; the databases contain some data on groundwater (well water) quality. The Branch also maintains production data for municipal groundwater (and surface water) supplies.

5.3.4 Evaluation of the Water Quality Databases in Saskatchewan

In 1986, Sask Water (Planning Branch) commissioned a consultant's report to identify and evaluate groundwater quality databases in the province and to examine the need for a provincially integrated groundwater database system (U. Roeper, personal communication, 1988). The consultant identified the following data sources:

i) data held by Saskatchewan Environment and Public Safety (groundwater data in Esquadat);

ii) groundwater data held by SRC;

iii) well water quality data from the H.E. Robertson Laboratory of Saskatchewan Health; and

iv) some groundwater quality data which are kept as part of the drilling and exploration records of Sask Water.

The consultant then recommended an integrated groundwater quality database, separate but interfaced with other groundwater databases. Planning for such a database should be coordinated between all four groups who have such data. In the interim, efforts should be made to adopt Esquadat (Environment Saskatchewan Quality Data Bank) coding for all groundwater quality data.

5.4 TECHNICAL ASSISTANCE

5.4.1 Technology Transfer

Technology transfer for well construction is provided primarily by the Saskatchewan Water Corporation. In other provinces the field inspectors who enforce well standards provide technology transfer for well drillers. Because there are no specific well construction standards in Saskatchewan, the Water Corporation needed no field inspectors, drilling equipment, etc.; other means had to be found.

In Saskatchewan, technology transfer is provided during the annual test drilling clinic organized by the Water Corporation. During the clinic a test hole is drilled, electric logging units are calibrated by factory technicians, and well drillers are instructed in the interpretation of electric logs.

5.4.2 Technical (and Financial) Assistance for the Collection of Electric Logs

Sask Water requires well logs from drillers and strongly promotes the use of electric logs. Technical and financial assistance (Test Drilling Grants, see Section 5.5.2) is made available for this purpose (approximately 40 commercial electric logging units are currently operating in the province).

5.4.3 Assistance with Well Problems

The regional offices of the Water Corporation (Operations Division) deal with all inquiries regarding wells. Well users or owners call the regional office if they have a problem. On request from the regional office, the Resource Management Division will provide advice and technical support. Corporation staff will not drive out and inspect wells personally but they will provide advice over the telephone. They will try to identify the problem and then refer the well owner to a well-servicing company. If analyses of water quality is necessary, the well owner will be referred to Saskatchewan Environment and Public Safety.

5.4.4 Analyses of Small and Private Water Supplies

Saskatchewan Health (Public Health Inspection) will provide free sample bottles and free water analyses for residential and other private wells. Analyses are for common drinking water parameters (coliform, major ions, Fe, NO_3, SO_4, some metals, etc.). More detailed major ion analyses are available at reduced cost. The analyses of gasoline and other organic contaminants (except for trihalomethanes) have to be performed by other laboratories.

Saskatchewan Health will also regularly sample public (non-municipal) water supplies with a flow rate of less than 18 m^3 a day. Saskatchewan Environment and Public Safety (Water Quality Branch) provides advice on water quality problems.

5.4.5 Spill Response

The Spill Response and Control Section of Saskatchewan Environment (Air and Land Protection Branch) provides emergency spill response in the form of a 24-hour spill response centre and a spill response team.

5.4.6 Assistance in the Establishment of Municipal Landfill Sites

Saskatchewan Environment and Public Safety (Air and Land Protection Branch) provides operational and technical advice in the selection and establishment of landfill sites, particularly to communities with a population of fewer than 5,000 inhabitants.

5.4.7 Inspection of Residential Sewage Disposal Systems

Regional inspectors from Saskatchewan Health (Public Health Inspection) will inspect the construction of residential sewage disposal. Municipal inspectors carry out these inspections in Regina and Saskatoon; federal inspectors provide this service on federal lands.

5.5 FINANCIAL ASSISTANCE

5.5.1 Grants for Deep Water Wells

Sask Water (Operations Division, Regional Offices) provides financial assistance (one-third of the cost of well development) for completing wells at depths greater than those covered by PFRA (71.8 m).

5.5.2 Grants for Test Drilling and Recording of E-Logs

Sask Water (Operations Division, Regional Offices) provides grants up to 50 percent or $9.84/m to the well owner for the costs of drilling for the purpose of collecting E-logs. The grant is only paid for testholes completed to the base of groundwater exploration or for boreholes completed as water wells.

5.5.3 Assistance with Municipal Water and Wastewater Systems

Sask Water (Operations Division, Regional Offices) has a financial assistance program for initial assessment, planning, and construction of municipal water and waste water systems for towns, villages, and hamlets (cities are not covered). The work is usually done by a consultant. The municipality may ask Sask Water for advice and investigations.

5.5.4 Well Assistance Program of the Prairie Farm Rehabilitation Administration

The PFRA provides technical assistance for the construction of wells. Evaluation and construction supervision is provided for group and community wells, either by PFRA

or by the province. Evaluation is only provided for a portion of individual wells. Compliance with American Water Well Association standards is required for all PFRA-assisted municipal wells.

The PFRA also provides grants for the construction of farm wells. For small diameter wells, financial assistance is available at the lesser of 1/3 of total eligible cost or $23 per metre to a maximum of $1,650. Wells serving more than one user may be eligible for higher support. For large diameter wells financial assistance is based on 1/3 of eligible cost or $54 per metre of cribbed depth plus one third the cost of a large diameter screen, whichever is less. PFRA should be consulted for specific details including the amount of financial assistance available, information required upon application, technical requirements and possible funding exceptions.

5.6 PESTICIDE CONTAINER DISPOSAL PROGRAM

In response to public concern, Saskatchewan Environment and Public Safety established the Pesticide Container Disposal Program to provide an environmentally acceptable means for the disposal of pesticide containers. To that end, the Department (Air and Land Protection Branch) has taken the following steps:

i) has set up guidelines for temporary collection sites;

ii) advises municipalities on the establishment of sites;

iii) reviews and approves the location of temporary collection sites as proposed by municipalities who wish to participate in the program;

iv) hires contractors to crush and remove containers and collect and dispose of pesticide residues; and

v) administers the contracts.

5.7 POLICY ON DEEP-WELL INJECTION

Saskatchewan Energy and Mines (Oil and Natural Gas Division) approves, monitors and inspects all deep-well disposal which may affect water resources. The Department thus requires licensing of withdrawal of water and use of injection wells for enhanced oil recovery. In Saskatchewan, liquid wastes of the same type as that which already exist in the disposal formation may be disposed of by deep-well injection, subject to the approval of Saskatchewan Energy and Mines.

If it is desired to dispose of liquid wastes containing constituents foreign to the disposal formation, an environmental impact assessment must first be carried out in accordance with the Environmental Assessment Act. If the assessment is favourable, a

permit may be issued by Saskatchewan Environment to allow for the disposal of the waste by deep-well injection (Bernier, personal communication, 1988).

5.8 WATER QUALITY OBJECTIVES

Provincial Water Quality Objectives for a series of constituents have been established. New or revised objectives are being developed by Saskatchewan Environment and Public Safety (Water Quality Branch). The basis for these objectives will be the new (1989/1990) Canadian Water Quality Guidelines. The objectives are intended primarily for surface waters, but they are applicable to groundwater for certain uses.

5.9 LABORATORIES AVAILABLE FOR GROUNDWATER ANALYSES

There are no private laboratories in Saskatchewan performing water analyses. Government laboratories which provide well water or groundwater analyses are listed below. Some of these laboratories require cost recovery for part or all of their analyses. Analyses that cannot be performed by the laboratories listed below have to be done outside the province. Provincial needs are coordinated by the Water Quality Branch of Saskatchewan Environment and Public Safety which has arrangements with various laboratories (e.g. Environment Canada's laboratory in Burlington, Ontario and Agriculture Canada's laboratory in Ottawa, Ontario). Agriculture Canada's laboratory in Ottawa, Ontario will also do some pesticide work.

Laboratory	Type of Analyses
Saskatchewan Health (H.E. Robertson Laboratory) Regina	chemical, microbiological, and trihalomethanes
Saskatchewan Research Council, Saskatoon	major ions, trace elements, radiochemicals and selected organics (including agricultural chemicals)
Regina Research Station of Agriculture Canada	herbicides
Saskatoon Research Station of Agriculture Canada	insecticides, some fungicides

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